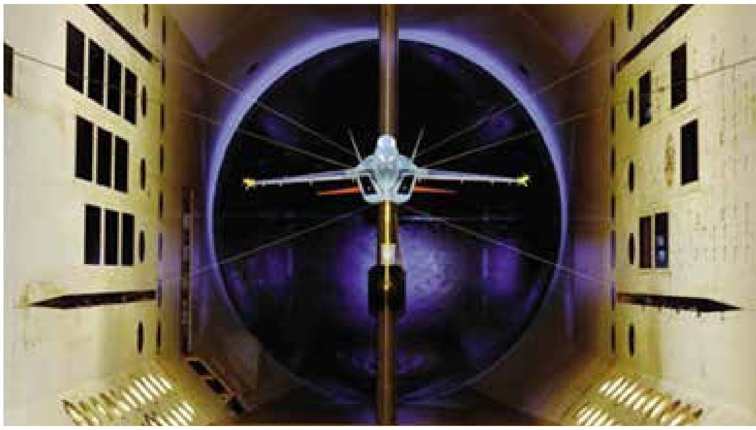
PRECISION FILTERS, INC.
On the New Frontiers of Precision

Application Note
AN-3

Wind Tunnels



Courtesy NASA

Introduction

The Transonic Dynamics Tunnel (TDT), located at NASA Langley in Hampton, VA USA, is a continuous flow tunnel used to study aero-elasticity on fixed wing and rotary wing aircraft at transonic speeds. The TDT test section is 16-foot square and is 8-feet long. The TDT is used extensively for a wide variety of tests, including propulsion systems, free flight, flutter, buffet, aero acoustics, and tests that involve real time control, such as flutter suppression. Nearly every U.S.-built launch vehicle, high-performance military aircraft, and commercial transport aircraft has been tested in the TDT since 1960.

Testing in the TDT requires the acquisition and display of 512 channels of real-time static and dynamic data. Data must be simultaneously acquired, stored, analyzed, and provided to a real-time control system for model control. A variety of sensors, such as strain gages, silicon diaphragm pressure sensors, piezo-resistive accelerometers, and hot-film anemometers, are used to measure model response during test, and actuators are used when model control is desired.

Often, time correlation of sensor data is critical to understand dynamic model response, particularly when the coherence between two sensors is to be determined. The measurement system must have outstanding channel-to-channel matching properties even at different programmed gain settings to avoid introducing artifacts during coherence analysis. Tests performed in the TDT are varied, from steady-state flow measurements to highly transient flutter, buffet, and aero acoustic measurement modes. The measurement system transfer function must be adaptable to a transient or steady-state test requirement.

With a system of 512 sensors, automated techniques are required to verify measurement system performance prior to each test, including sensors and cables when practical. With relatively long test durations, the continuous monitor and display of sensor excitation and sensor resistance during the test are highly desired as a means to verify sensor health. Also, fully automated, traceable annual calibration of the system is required.

Solution

To compare signal conditioning vendors, NASA purchased small evaluation systems and put the hardware through a series of rigorous qualification tests. Tests included DC and AC gain accuracy, DC excitation accuracy, DC stability, broadband and spectral noise, wideband and filtered frequency response, transient response, passband flatness, and amplitude and phase match.

Precision Filters, Inc. (PFI) 28000 Signal Conditioning System was selected to provide the analog signal conditioning for the 512 sensors that are installed on the test model. The system requirements were supported by the PFI 28124 quad-channel transducer conditioner card, and the 512-channel system is housed in 84″ of rack space. The outputs of the 28124 card were routed to a National Instruments PXI analog-to-digital converter system. Cabling to the sensors and the A/D system is accomplished via the rear of the 28000 chassis, and signal conditioning cards can be inserted and removed from the 28000 chassis without disconnecting the input/output cables.

Solution Highlights

- **512-channel universal signal conditioning system for wind tunnel measurements**
- **Support for a wide variety of transducers using one common signal conditioning card**
- **Bipolar constant voltage (zero common-mode) or balanced constant current excitation**
- **Fully programmable sensor bridge configuration—quarter, half, or full-bridge completion, 120, 350 or 1000 ohm completion resistors**
- **Fully programmable constant current configuration—2-wire/4-wire (Kelvin) connection**
- **Outstanding amplitude and phase matching independent of amplifier gain setting**
- **Programmable low-pass filter FLAT/PULSE frequency response for time-domain or frequency-domain analysis**
- **Programmable low-pass filter cutoff frequency—1 Hz to 100 kHz**
- **Programmable AC/DC coupling**
- **Three buffered outputs per sensor channel, independently programmable for wideband or filtered mode with output ground sense for driving single-ended loads without ground loops**
- **High density—only 84 inches of rack space for 512 channels**
- **Automated validation of sensor, cable, signal conditioner, and DAS**
- **Proprietary dynamic shunt calibration for evaluation of AC system response, including sensor and cables**
- **Fully automated NIST-traceable calibration tests performed in place**

Solution (continued)

The 28124 card provides a high-performance, high-density, fully programmable, universal solution for conditioning the wide variety of sensors that NASA uses. The 28124 provides constant voltage for bridge type sensors or proprietary 2-wire/4-wire (Kelvin connection) constant current excitation for variable resistance sensors, such as dynamic strain gages or RTDs. Three independently buffered outputs per channel are supplied. One output is routed to the PXI A/D system, another is used by engineers to perform real-time analysis and model control, and a third is used for the customer-supplied data acquisition system and for critical tunnel parameter and channel data. Each output supports ground sensing for driving grounded single-ended loads without introducing ground loops and may be independently programmed for filtered or wideband operation.

Precision Filters' FLAT/PULSE filter technology allows the user to set the frequency response characteristics of the signal conditioner under program control. For transient tests or tests where time-domain wave shape preservation is important, the PULSE mode characteristic is used. PULSE mode provides linear phase response, which is required for time-domain wave shape reproduction, and outstanding transient response with low overshoot and ringing. For frequency-domain analysis, selecting the FLAT filter characteristic will result in excellent transfer function flatness and a sharp, selective filter response.

The 28124 conditioner features outstanding channel-to-channel amplitude and phase matching characteristics, even when the amplifier is programmed to different gains on different channels. Matching of 0.1 dB and 1° is specified throughout the passband of the filter, with cutoff frequencies programmable from 1 Hz to 100 kHz.

Courtesy NASA

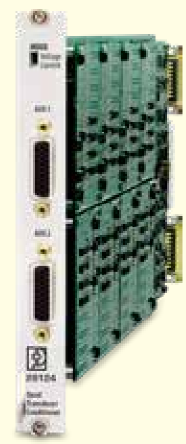
NASA requires high-performance equipment with features that ensure valid data collection, as wind tunnel testing is expensive and often there is one—and only one—chance to collect the data. Quick and easy visibility of cable and sensor health can allow timely corrective actions that can save crucial data.

Built-in test hardware and software allow the user to easily run a series of automated sensor and cable health checks. Precision Filters' proprietary dynamic shunt calibration techniques are used to verify sensor resistance and rolloff effects due to cable capacitance.

All test and measurement systems require periodic calibration. Typically, this means test systems are dismantled and cards are uninstalled and shipped either to an in-house cal lab or back to the manufacturer, requiring 30 days of downtime. NASA requires automated in-situ calibration, as the test schedule would not tolerate one month per year of downtime for equipment calibrations. Precision Filters' built-in test hardware and software allow the user to perform NIST-traceable calibration tests on site—without removing the system from the equipment rack. .

PFI Equipment Used in NASA Tests

Qty. 8 28016 Mainframes with Power Supplies and 28000F-BIF1-FT Control Cards with Built-In Test Support



Qty. 128 28124-LP4FP Quad Universal Transducer Conditioners

Qty. 1 28000-TEST Test Subsystem for performing system validation and in-situ NIST-traceable calibrations

For more information, please contact Doug Firth, Precision Filters, Inc. at 607-277-3550 or doug@pfinc.com.

References:

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Cole, S. R.; Noll, T. E.; Perry III, B.: *Transonic Dynamics Tunnel Aeroelastic Testing in Support of Aircraft Development, Journal of Aircraft*. Vol. 40, No. 5, September–October 2003.

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http://www.aeronautics.nasa.gov/atp/facilities/documents/M187008_TDTPrint_508.pdf

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ISO 9001 CERTIFIED QUALITY

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